VALVE ACTUATION SYSTEM WITH VALVE SEATING CONTROL

FIELD OF THE INVENTION

[0001] The present invention relates generally to systems and methods for controlling engine combustion chamber valves in an internal combustion engine. In particular, the present invention relates to systems and methods for actuating one or more engine valves with valve seating control.

BACKGROUND OF THE INVENTION

[0002] Engine combustion chamber valves, such as intake and exhaust valves, are typically spring biased toward a valve closed position. In many internal combustion engines, the engine valves may be opened and closed by fixed profile cams in the engine. More specifically, valves may be opened or closed by one or more fixed lobes which may be an integral part of each of the cams. In some cases, the use of fixed profile cams may make it difficult to adjust the timings and/or amounts of engine valve lift. It may be desirable, however, to adjust valve opening times and lift for various engine operating conditions, such as different engine speeds.

[0003] A method of adjusting valve timing and lift, given a fixed cam profile, has been to incorporate a "lost motion" device in the valve train linkage between the valve and the cam. Lost motion is the term applied to a class of technical solutions for modifying the valve motion dictated by a cam profile with a variable

length mechanical, hydraulic, or other linkage means. The lost motion system comprises a variable length device included in the valve train linkage between the cam and the engine valve. The lobe(s) on the cam may provide the "maximum" (longest dwell and greatest lift) motion needed for a range of engine operating conditions. When expanded fully, the variable length device (or lost motion system) may transmit all of the cam motion to the valve, and when contracted fully, transmit none or a reduced amount of cam motion to the valve. By selectively decreasing the length of the lost motion system, part or all of the motion imparted by the cam to the valve can be effectively subtracted or lost.

[0004] Hydraulic-based lost motion systems may provide a variable length device through use of a hydraulically extendable and retractable piston assembly. The length of the device is shortened when the piston is retracted into its hydraulic chamber, and the length of the device is increased when the piston is extended out of the hydraulic chamber. One or more hydraulic fluid control valves may be used to control the flow of hydraulic fluid into and out of the hydraulic chamber.

[0005] One type of lost motion system, known as a Variable Valve Actuation (VVA) system, may provide multiple levels of lost motion. Hydraulic VVA systems may employ a high-speed control valve to rapidly change the amount of hydraulic fluid in the chamber housing the hydraulic lost motion piston. The control valve may also be capable of providing more than two levels of hydraulic fluid in the chamber, thereby allowing the lost motion system to attain multiple lengths and provide variable levels of valve actuation.

[0006] Typically, engine valves are required to open and close very quickly, and therefore the valve return springs are generally relatively stiff. If left unchecked after a valve opening event, the valve return spring could cause the valve to impact its seat with sufficient force to cause damage to the valve and/or its seat. In valve actuation systems that use a valve lifter to follow a cam profile, the cam profile provides built-in valve closing velocity control. The cam profile may be formed so that the actuation lobe merges gently with cam base circle, which acts to decelerate the engine valve as it approaches its seat.

[0007] In hydraulic lost motion systems, and in particular VVA hydraulic lost motion systems, rapid draining of fluid from the hydraulic circuit may prevent the valve from experiencing the valve seating provided by cam profile. In VVA systems, for example, an engine valve may be closed at an earlier time than that provided by the cam profile by rapidly releasing hydraulic fluid from the lost motion system. When fluid is released from the lost motion system, the valve return spring may cause the engine valve to "free fall" and impact the valve seat at an unacceptably high velocity. The valve may impact the valve seat with such force that it eventually erodes the valve or valve seat, or even cracks or breaks the valve. In such instances, engine valve seating control may be desired because the closing velocity of the valve is governed by the release of hydraulic fluid from the lost motion system instead of by a fixed cam profile. Accordingly, there is a need for valve seating devices in engines that include lost motion systems, and most notably in VVA lost motion systems.

[0008] In order to avoid a damaging impact between the engine valve and its seat, the valve seating device should oppose the closing motion regardless of the position of other valve train elements. In order to achieve this goal, the point at which the engine valve experiences valve seating control should be relatively constant. In other words, the point during the travel of the engine valve at which the valve seating device actively opposes the closing motion of the valve should be relatively constant for all engine operating conditions. Accordingly, it may be advantageous to position the valve seating device such that it can oppose the closing motion of the engine valve without regard to the position of intervening valve train elements, such as rocker arms, push tubes, or the like.

[0009] The valve seating device may include hydraulic elements, and thus may need to be supported in a housing and require a supply of hydraulic fluid, yet at the same time fit within the packaging limits of a particular engine. It may also be advantageous to locate the valve seating device near other hydraulic lost motion components. By locating the valve seating device near other lost motion components, housings, hydraulic feeds, and/or accumulators may be shared, thereby reducing bulk and the number of required components.

[0010] A valve seating device may be constructed so that a significant portion of the opposing force it applies to a closing engine valve occurs during the last millimeter of travel of the valve. As a result, control of the amount of lash space between the valve seating device and the engine valve or other intervening elements may be critical to proper operation of the valve seating device. Factors such as component thermal growth, valve wear, valve seat wear, and tolerance

stack-up can affect the amount of lash. Some known valve seating devices have required manual lash adjustment or a separate set of lash adjustment hardware. Accordingly, it may be advantageous to have a valve seating device that self-adjusts for lash differences between the engine valve and the valve seating device.

[0011] Various embodiments of the present invention may meet one or more of the aforementioned needs and provide other benefits as well.

SUMMARY OF THE INVENTION

[0012] Applicant has developed an innovative valve actuation system having valve seating control. In one embodiment, the system comprises: a housing; a lost motion system disposed in the housing; a rocker arm having a first contact surface, a second contact surface, and a third contact surface, the first contact surface operatively contacting the engine valve, and the second contact surface operatively contacting the lost motion system; and a valve seating device disposed in the housing, operatively contacting the third contact surface.

[0013] Applicant has further developed an innovative system for controlling the seating velocity of an engine valve in an internal combustion engine. In one embodiment, the system comprises: a housing; a lash piston slidably disposed in a bore formed in the housing, the lash piston having a cavity formed therein; and a seating piston slidably disposed in the cavity.

[0014] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only, and are

not restrictive of the invention as claimed. The accompanying drawings, which are incorporated herein by reference, and which constitute a part of specification, illustrate certain embodiments of the invention and, together with the detailed description, serve to explain the principles of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] In order to assist in the understanding of the invention, reference will now be made to the appended drawings, in which like reference characters refer to like elements. The drawings are exemplary only, and should not be construed as limiting the invention.

[0016] Figure 1 is a schematic diagram of a valve seating control system in accordance with a first embodiment of the present invention.

[0017] Figure 2 is a schematic diagram of a valve seating control system in accordance with a second embodiment of the present invention.

[0018] Figure 3 is a cross-section of a valve seating control system in accordance with a third embodiment of the present invention.

[0019] Figure 4 is a cross-section detail view of a valve seating device in accordance with an embodiment of the present invention.

[0020] Figure 5 is a cross-section detail view of a valve seating device in accordance with an embodiment of the present invention.

[0021] Figure 6 is a cross-section detail view of a valve seating device in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

[0022] Reference will now be made in detail to a first embodiment of a valve seating control system **10** of the present invention, an example of which is illustrated in Fig. 1. The system **10** may include one or more valve train elements **300** operatively connected to a lost motion system **100**, a valve seating device **200**, and at least one engine valve **400**. The lost motion system **100** may receive an input from a motion imparting means **500**. The valve train element **300** may transmit a valve actuation motion to the engine valve **400**. The engine valve **400** may be actuated to produce various engine valve events, such as, but not limited to, main intake, main exhaust, compression release braking, bleeder braking, exhaust gas recirculation, early exhaust valve opening and/or closing, early intake opening and/or closing, centered lift, etc. The engine valve **400** may comprise an exhaust valve, intake valve, or auxiliary valve.

[0023] The motion imparting means **500** may comprise any combination of cam(s), push-tube(s), rocker arm(s) or other mechanical, electro-mechanical, hydraulic, or pneumatic device for imparting a linear actuation motion. The motion imparting means **500** may receive motion from an engine component and transfer the motion as an input to the lost motion system **100**.

[0024] The lost motion system **100** may comprise any structure that connects the motion imparting means **500** to the valve train element **300** and which is capable of selectively losing part or all of the motion imparted to it by the motion imparting means **500**. The lost motion system **100** may comprise, for example, a

variable length mechanical linkage, hydraulic circuit, hydro-mechanical linkage, electro-mechanical linkage, and/or any other linkage provided between the motion imparting means **500** and the valve train element **300** and adapted to attain more than one operative length. If the lost motion system **100** incorporates a hydraulic circuit, it may include means for adjusting the pressure or the amount of fluid in the hydraulic circuit, such as, for example, trigger valve(s), check valve(s), accumulator(s), and/or other devices used to release hydraulic fluid from, or add hydraulic fluid to, a hydraulic circuit.

[0025] The engine valve **400** may be disposed within a sleeve **420**, which in turn is provided in a cylinder head **410**. The engine valve **400** may be adapted to slide up and down relative to the sleeve **420** and may be biased into a closed position by a valve spring **450**. The valve spring **450** may be compressed between the cylinder head **410** and a valve spring retainer **440** that may be attached to the end of a valve stem, thereby biasing the engine valve **400** into an engine valve seat **430**. When the engine valve **400** is in contact with the engine valve seat **430**, the engine valve **400** is effectively in a closed position.

[0026] The one or more valve train elements **300** may receive a force from the lost motion system **100** and may transfer this force to the engine valve **400**. The one or more valve train elements **300** may also transmit the force of the valve spring **450** that biases the engine valve **400** into a closed position back to the lost motion system **100** and/or the valve seating device **200**.

[0027] The valve seating device **200** is operatively connected to the valve train element **300**. When the valve seating device **200** is activated, it may

provide a resistance to the bias of the engine valve spring **450** through the valve train element **300**. In a preferred embodiment, the valve seating device **200** is constantly activated. It is contemplated, however, that the valve seating device **200** may be deactivated when a user desires, so that it does not operate to seat the engine valve **400**. When the valve seating device **200** is deactivated, the engine valve **400** may seat under the bias of the engine valve spring **450** and/or the lost motion device **100**.

[0028] Under either a positive power engine mode or when the lost motion system **100** is not activated to lose motion, motion may be transferred from the motion imparting means **500** to the engine valve **400** through the valve train element **300**. Likewise, the force of the engine valve spring **450** may be transferred from the engine valve spring **450**, through the valve train element **300**, and to the lost motion system **100** and/or the valve seating device **200**. However, when the lost motion system **100** acts to lose the motion of the motion imparting means **500**, the engine valve **400** normally may close in a "free-fall," a state in which the engine valve **400** may contact the engine valve seat **430** at an undesirably high rate of speed. In order to slow the velocity at which the engine valve **400** closes when the lost motion system **100** is losing motion, the valve seating device **200** may be used.

[0029] The valve seating device **200** may slow the speed at which the engine valve **400** contacts the engine valve seat **430** by opposing the motion of the engine valve **400** through the valve train element **300**. The valve seating device **200** may slow the seating velocity of the engine valve **400**, preferably in a

progressive manner, and particularly in the last millimeter of travel, thereby reducing the wear and damage on both the engine valve **400** and the engine valve seat **430**.

[0030] A second embodiment of the present invention is illustrated in Fig. 2, in which like reference characters refer to like elements. With reference thereto, the valve train element **300** may comprise a rocker arm **310**. The rocker arm **310** may be disposed pivotally on a shaft **315**, and may include a first contact surface **301** for operatively contacting the engine valve **400**, a second contact surface **302** for operatively contacting the lost motion system **100**, and a third contact surface **303** for operatively contacting the valve seating device **200**. The rocker arm **310** may pivot about the shaft **315** so as to transmit motion from one side of the pivot point to the other. In this manner, the rocker arm **310** may receive input motion from the lost motion system **100** and/or the valve seating device **200** and may transmit this motion to the engine valve **400**. The rocker arm **310** may also transmit motion from the engine valve **400** to the lost motion system **100** and/or to the valve seating device **200** in a similar manner.

[0031] The third contact surface **303** may be situated such that the point during the travel of the engine valve at which the valve seating device actively opposes the closing motion of the valve is relatively constant for all engine operating conditions. As shown in Fig. 2, the second contact surface **302** may be located between the first contact surface **301** and the third contact surface **303**. However, it is appreciated that the third contact surface **303** may be located at

any point on the rocker arm **310** that has a unique position when the engine valve **400** is in a closed position.

[0032] In one embodiment of the present invention, as shown in Fig. 2, the system **10** may further comprise a control circuit **600**. The control circuit **600** may provide the lost motion system **100** and the valve seating device **200** with control inputs for activating and/or deactivating the lost motion system **100** and the valve seating device **200**. The control inputs may be hydraulic fluid, electric signals, mechanical actuations, pneumatic actuations, electro-mechanical actuations, hydro-mechanical actuations, and/or any other suitable input for controlling operation of the systems.

[0033] In one embodiment of the present invention, the control circuit **600** may comprise a hydraulic fluid supply circuit. The control circuit **600** may supply constant fluid pressure to the valve seating device **200** such that it is activated and may actuate to slow the seating velocity of the engine valve **400**. Depending on the engine operating mode, the control circuit **600** may selectively activate the lost motion system **100**. When the lost motion system **100** is activated, it may lose all or part of the motion received from the motion imparting means **500**, and thus may not supply motion to the rocker arm **310** and therefore to the engine valve **400**.

[0034] A third embodiment of the present invention is illustrated in Fig. 3, in which like reference characters refer to like elements. The lost motion system **100** and the valve seating device **200** may be disposed in a housing **700**. In one embodiment, the lost motion system **100** may comprise a collapsible tappet

assembly having a master piston **110** and a slave piston **120**. The master piston **110** may be slidably disposed in a bore **710** formed in the housing **700** such that it may slide back and forth in the bore **710** while maintaining a hydraulic seal with the housing **700**. The slave piston **120** may be slidably disposed within the master piston **110** such that it may slide relative to the bore **710** while maintaining a hydraulic seal with the master piston **110**. Hydraulic fluid may be selectively supplied to the lost motion system **100** between master piston **110** and the slave piston **120** through a passage **610**.

[0035] In one embodiment of the present invention, as shown in Fig. 3, the slave piston **120** may further include an extension **125** having a first end contacting the slave piston **120** and a second end contacting the second contact surface **302** of the rocker arm **310**. Alternatively, it is contemplated that the slave piston **120** may contact the rocker arm **310** directly. Other suitable means for supplying motion to the rocker arm **310** through the lost motion system **100** are considered well within the scope and spirit of the present invention.

[0036] In the embodiment of the present invention shown in Fig. 3, the motion imparting means **500** includes a push tube assembly **510**. The push tube assembly **510** may contact and impart motion to one end of the master piston **110**. The push tube **510** may receive engine valve actuation motion from one or more cams (not shown). In an alternative embodiment, the cam may act directly on the master piston **110** without the push tube **510**.

[0037] A control circuit **600** element, such as, for example, a trigger valve (not shown) may be disposed in the passage **610**. When motion transfer is required,

the trigger valve may be closed such that fluid is trapped between the master piston **110** and the slave piston **120**, creating a hydraulic lock. Motion from the pushtube **510** is transmitted through the master piston **110** and the slave piston **120** to the rocker arm **310**, which, in turn, causes the engine valve **400** to open. When motion transfer is not required, the trigger valve is opened and fluid is permitted to flow in and out of the space between the master piston **110** and the slave piston **120**. All, or a portion of, the motion applied to the master piston **110** is then "lost."

[0038] Fig. 4 is a cross-section of the valve seating device **200** in accordance with an embodiment of the present invention. The valve seating device **200** may comprise a lash piston **210** slidably disposed in a second bore **720** formed in the housing **700**, and a seating piston **220** slidably disposed within a cavity **206** formed in the lash piston **210**. The lash piston **210** may be adapted to slide relative to the bore **720** while at the same time maintaining a seal with the bore **720**. The seating piston **220** may be adapted to slide within the cavity **206** while maintaining a seal with the lash piston **210**.

[0039] A spring **250** having a first end in contact with the housing **700** and a second end in contact with the seating piston **220** biases the seating piston **220** in an upward direction relative to the bore **720**. Downward translation of the seating piston **220** within the cavity **206** may be limited by a retaining ring **260** formed in the lash piston **210**.

[0040] In one embodiment of the present invention, a check disk **230** may be disposed between the lash piston **210** and a piston head **225** extending from the

seating piston **220**. A fluid slot **205** and a fluid opening **208** may be formed within the lash piston **210** above the check disk **230**. A spring **240** having a first end in contact with the seating piston **220** and a second end in contact with the check disk **230** biases the check disk **230** away from the piston head **225** against a shoulder **212** formed in the lash piston **210**. In this position, the check disk may substantially cover the fluid opening **208**.

[0041] Hydraulic fluid supply may communicate to the valve seating device **200** through a hydraulic passage **620** formed in the housing **700**. The hydraulic passage **620** may terminate at the bore **720**, and may communicate fluid to the fluid slot **205** through an annulus **215** formed in the lash piston **210**. During operation, fluid may communicate between the cavity **206** and the hydraulic passage **620** through a bleed orifice **235** formed in the check disk **230**, and the fluid opening **208** and the fluid slot **205**.

[0042] It is appreciated that some fluid supplied through the passage **620** may leak past the seal formed between the lash piston **210** and the housing **700** into a lash chamber **207** below the lash piston **210**. The pressure created by the fluid in the lash chamber **207** may cause the lash piston **210** to rise within the bore **720**. This may cause the upper surface **211** of the lash piston **210** to contact the third contact surface **303** of the rocker arm **310**, taking up any lash that may exist between the valve seating device **200** and the rocker arm **310**.

[0043] Operation of the system **10** will now be described with reference to Figs. 3 and 4. When motion transfer is required, hydraulic fluid is supplied to the lost motion system **100** through the passage **610**. The fluid may fill the space

between the master piston **110** and the slave piston **120**. The control circuit **600** may close the trigger valve (not shown) disposed in the passage **610**, preventing the fluid from flowing out of the lost motion system **100** and creating a hydraulic lock. As a result, the motion imparted to the master piston **110** is transferred to the slave piston **120**. The slave piston **120**, in turn, transfers the motion through the rocker arm **310** to the engine valve **400**.

[0044] Hydraulic fluid is also supplied to the valve seating device **200** through the passage **620**. The fluid flows through the annulus **215** into the fluid slot **205**. As discussed above, some of the fluid may leak into the lash chamber **207** and cause the upper surface **211** of the lash piston **210** to contact the third contact surface **303** of the rocker arm **310**, taking up any system lash.

[0045] As motion is transferred from the lost motion system **100** to the rocker arm **310**, the rocker arm **310** rotates in a clockwise direction and actuates the engine valve **400** at the first contact surface **301**. As the rocker arm **310** rotates clockwise to open the engine valve **400**, the third contact surface **303** on the rocker arm **310** may move away from the lash piston **210**.

[0046] At this point, the fluid entering the fluid slot **205** through the annulus **215** may push down on the check disk **230** and up on the lash piston **210**. The hydraulic pressure causes the lash piston **210** to move upwards, and the seating piston **220** to move downwards, separating the check disk **230** from its seat against the shoulder **212** and allowing fluid to enter the cavity **206**. The seating piston **220** continues to move down until it hits the retaining ring **260**. At this point, the hydraulic pressure below the check disk **230** and the bias of the spring

240 cause the check disk **230** to return to its seat against the shoulder **212**, covering the fluid opening **208** and trapping fluid in the cavity **206**. The valve seating device **200** is now charged, and ready to perform its seating function.

[0047] As the engine valve **400** closes, the rocker arm **310** may rotate counter-clockwise until the third contact surface **303** on the rocker arm **310** contacts the upper surface **211** of the lash piston **210**. The lash piston **210** may then be forced downward, pressurizing the hydraulic fluid below it. The downward force of the lash piston **210** squeezes the area of the cavity **207**, increasing the pressure in the cavity **207**, and forcing the seating piston **220** upward. The upward motion of the seating piston **220** squeezes the area of the cavity **206**, forcing fluid to flow through the bleed orifice **235**. At the same time, the bias of the spring **250** forces the seating piston **220** upward within the cavity **206**. Because of the relatively small size of the bleed orifice **235**, the flow of fluid from the cavity **206** through the bleed orifice **235** creates a retarding force that slows the downward motion of the lash piston **210**, and, in turn, the motion of the rocker arm **310**, and, ultimately the seating velocity of the engine valve **400**. The fluid exiting the cavity **206** may flow through the annulus **215** and the passage **620** to the control circuit **600**.

[0048] The rate of fluid flow through the bleed orifice **235**, and, correspondingly, the amount of retarding force created, is dependant on the flow area through the orifice. The flow area through the orifice is regulated by the proximity of the piston head **225** and the bleed orifice **235**. When the rocker **310** first contacts the valve seating device **100**, and the lash piston **210** begins to

move downward, the distance between the piston head **225** and the bleed orifice **235**, and, accordingly, the size of the flow area, is greatest. The high velocity of the closing engine valve creates a high flow rate through the bleed orifice **235** and a significant retarding force. As the valve slows and approaches its seat, the distance between the piston head **225** and the bleed orifice **235**, and, thus, the flow area through the orifice, becomes progressively smaller. As a result of the lower seating velocity and the smaller flow area, a more constant retarding pressure is produced.

[0049] Another embodiment of the valve seating device **200** is shown with reference to Fig. 5, in which like reference characters refer to like elements. The valve seating device **200** may further comprise a stationary bushing member **213** disposed in the bore **720**, and a contact pin **214** slidably disposed in the bushing member **213**. In the position shown in Fig. 5, the contact pin **214** may have a first end in contact with the third contact surface **303** of the rocker arm **310** and a second end in contact with the lash piston **210**. A spring **270** may bias the lash piston **210** and the seating piston **220** against the contact pin **214**.

[0050] In one embodiment of the present invention, hydraulic fluid pressure below the pin **214** may act on the pin **214** such that the pin **214** remains in contact with the rocker arm **310** during the full rocker arm stroke. In this embodiment, there may be no impact between the pin **214** and the rocker arm **310**. Correspondingly, the noise associated with the valve seating device **200** may be reduced. In an alternative embodiment, the pin **214** may have a limited stroke such that the pin **214** and the rocker arm **310** may separate during rotation

of the rocker arm **310**. The size and/or material composition of the pin **214** may be designed such that the impact force that occurs when the pin **214** and the rocker arm **310** reconnect is reduced.

[0051] Operation of the valve seating device **200** shown in Fig. 5 will now be described. Hydraulic fluid is supplied to the valve seating device **200** through the passage **620**. The fluid flows into the fluid slot **205** underneath the pin **214**. At this point, the fluid entering the fluid slot **205** may push up on the pin **214**. Because the pin **214** has a diameter that is relatively small as compared with the diameter of the bore **720**, the force acting on the rocker arm **310**, and subsequent rocker arm rotation, due to the upward motion of the pin **214** may be reduced. As a result, unwanted force acting in the valve opening direction on a closed engine valve **400** is also reduced.

[0052] The bias of the spring **270** causes the lash piston **210** to move upward, contacting the pin **214** and removing the lash from the system. Fluid pressure acting on the pin **214** may bias the pin **214** such that it remains in contact with the rocker arm **310** during the full rocker arm stroke. As discussed above, in this embodiment, rocker-to-pin impact may be reduced or eliminated, which, in turn, may result in reduced noise during valve seating operation.

[0053] As the rocker arm **310** rotates in the valve opening direction, and the third contact surface **303** moves upward, the pin **214** also moves upward. This, in turn, allows the lash piston **210** to move upward. The upward motion of the lash piston **210** increases the volume of cavity **207**, and correspondingly, decreases the pressure of the hydraulic fluid in the cavity **207**. The reduced

pressure in the cavity **207** and the pressure above the seating piston **220** causes the seating piston **220** to move downward. The seating piston **220** continues to move down until it hits the retaining ring **260**, or a base for the spring **250** as shown in Fig. 5. At this point, the hydraulic pressure below the check disk **230** and the bias of the spring **240** cause the check disk **230** to return to its seat against the shoulder **212**, covering the fluid opening **208** and trapping fluid in the cavity **206**. The valve seating device **200** is now charged, and ready to perform its seating function.

[0054] As the engine valve **400** closes, the rocker arm **310** may rotate in the valve closing direction. The rotation of the rocker arm **310** forces the pin **214** downward, contacting the lash piston **210**. Because the impact between the lash piston **210** and the pin **214** occurs in an oil-filled area above the slot **205** in the bore **720**, some or all of the noise generated may be damped. The lash piston **210** may then be forced downward, pressurizing the hydraulic fluid below it. The downward force of the lash piston **210** squeezes the area of the cavity **207**, increasing the hydraulic pressure in the cavity **207** and forcing the seating piston **220** upward. The upward motion of the seating piston **220** squeezes the area of cavity **206**, forcing the fluid in the cavity **206** through the bleed orifice **235**. At the same time, the bias of the spring **250** forces the seating piston **220** upward within the cavity **206**. Because of the relatively small size of the bleed orifice **235**, the flow of fluid from the cavity **206** through the bleed orifice **235** creates a retarding force that slows the downward motion of the lash piston **210**, and, in turn, the motion of the rocker arm **310**, and, ultimately the seating velocity of the engine

valve **400**. The fluid exiting the cavity **206** may flow through the annulus **215** and the passage **620** to the control circuit **600**.

[0055] In another embodiment of the present invention, as shown in Fig. 6, the valve seating device **200** may operate without the check disk **235**. The size of the fluid opening **208** may be reduced such that the piston head **225** substantially covers the opening **208**. In this manner, the fluid opening **208** may operate like the bleed orifice **235** and provide the necessary valve seating retarding force.

[0056] In one embodiment of the present invention, the valve seating device **200** and the lost motion system **100** may be positioned so as to share the control circuit **600**. An accumulator may be located between the valve seating device **200** and the lost motion system **100**. The accumulator may absorb excess hydraulic fluid and re-supply such fluid to the valve seating device **200** and the lost motion system **100** as each system may require. However, it is appreciated that by positioning the lost motion system **100** near or adjacent to the valve seating device **200** many other advantages may be obtained. For example, the valve seating device **200** and the lost motion system **100** may be positioned so as to share fluid supply components and/or housings. Additionally, the overall weight of the valve seating control system **10** may be reduced.

[0057] It will be apparent to those skilled in the art that various modifications and variations can be made in the construction, configuration, and/or operation of the present invention without departing from the scope or spirit of the invention. For example, where lost motion functionality is not required, it is contemplated

that embodiments of the valve seating device **200** may be provided in a system without the lost motion system **100**.